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STUDIES ON HYBRID VIGOUR IN CASTOR

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Introduction

CASTOR (*Ricinus communis* Linn.) is an important oilseed crop and the possibility of utilising hybrid vigour for increasing its productivity has been indicated by several workers (Rapoport, 1948; Seshadri, 1958; Anubhava Narayan, 1958; Ramanamurthy and Narasimha Rao, 1959). Zimmerman and Parkey (1954) have outlined a technique for producing three-way hybrid castor utilising the pistillate F_1 hybrids that result from mating of two different lines of which one is the pistillate Nebraska 145-4. Parkey (1957) has recorded cytoplasmic influence in the determination of pistillate sex expression whereby the development of entirely pistillate progenies is made possible. The increase in yield obtained with hybrid castor in the U.S.A. has been phenomenal. The behaviour of hybrids resulting from Indian and American types of castor is detailed here.

Material and methods

Five inbred lines of castor are involved in this study. Crosses involving TMV 1, TMV 2 and TMV 3 strains as the female parents and the American types, Baker-195 and Cimarron as the male parents, were effected early in 1960 and the sowings were done in the first week of August, 1960. The six hybrids and five parents were compared in the field in row plots with four replications in randomised block design. The crop was raised under rainfed conditions without any basal dressing of manure before sowing.

Results and discussion

The mean increase or decrease in value of the different characters of the six hybrids

over the respective parents and over the superior parent are given as percentages in Tables 1 to 3. The significant features are outlined below :

Flowering date. The male parents in each case were the earliest to flower compared to the female parents and hybrids. All hybrids except TMV 1 \times Cimarron were later than the male parents but significantly earlier to flower when compared to their female parents.

Plant height. No significant heterotic effects were observed in any of the hybrids, although apparent positive deviations from the mid-parental value were recorded in three of the hybrids, namely, TMV 1 \times Cimarron, TMV 2 \times Cimarron and TMV 3 \times Cimarron.

Number of nodes up to the primary raceme. This character related to the earliness of the plant in flowering. No significant reduction in number of nodes over the earlier parent was observed in any of the hybrids. However, a significant feature was the difference in expression of period required for flowering in different hybrids. In the three hybrids where Cimarron was used as the male parent, the values for the hybrids almost approach the mid-parental value. But in the other three hybrids where Baker-195 was the male parent the number of days taken to flower tend to approach the values for the male parent which was earlier. Thus a shift towards earliness was evident in these cases.

Number of racemes. Except the combination TMV 2 \times Cimarron, all the hybrids exhibited significant differences over either

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TABLE 1

| Parents and hybrids | No. of days taken for flowering | | | | No. of nodes | | | | Duration in days | | | |
|--------------------------------|---------------------------------|-----------------------------------|----------------------|------------|-----------------------------------|---------------|------------|-----------------------------------|------------------|---|---|--|
| | Mean value | Difference of F ₁ from | | Mean value | Difference of F ₁ from | | Mean value | Difference of F ₁ from | | | | |
| | | Male parent (early) | Female parent (late) | | Male parent | Female parent | | Male parent | Female parent | | | |
| 1. TMV 1 (Female parent) .. | 55.05 | — | — | 14.55 | — | — | 185.00 | — | — | — | — | |
| 2. Baker-195 (Early parent) | 35.25 | — | — | 6.55 | — | — | 128.25 | — | — | — | — | |
| 3. TMV 1 × Baker-195 .. | 37.80* | +2.55 | -17.25 | 8.25* | +1.60 | -6.30 | 150.00* | +21.75 | -35.00 | — | — | |
| 4. TMV 2 (Female parent) .. | 64.50 | — | — | 20.65 | — | — | 189.75 | — | — | — | — | |
| 5. TMV 2 × Baker-195 .. | 37.25* | +2.00 | -27.25 | 7.80* | +1.15 | -12.85 | 165.25* | +37.00 | -24.50 | — | — | |
| 6. TMV 3 (Female parent) .. | 61.92 | — | — | 19.00 | — | — | 198.00 | — | — | — | — | |
| 7. TMV 3 × Baker-195 .. | 36.65* | +1.40 | -25.27 | 8.90* | +2.25 | -10.10 | 164.00* | +35.75 | -34.00 | — | — | |
| 8. Cimarron (Female parent) .. | 48.05 | — | — | 12.45 | — | — | 150.00 | — | — | — | — | |
| 9. TMV 1 × Cimarron .. | 52.45 | +4.40 | -2.60 | 13.95* | +1.50 | -0.60 | 164.00* | +14.00 | -21.00 | — | — | |
| 10. TMV 2 × Cimarron .. | 55.27* | +7.22 | -9.23 | 16.85 | +4.40 | -3.80 | 171.75* | +21.75 | -18.00 | — | — | |
| 11. TMV 3 × Cimarron .. | 55.40* | +7.35 | -6.52 | 15.40 | +2.95 | -3.60 | 175.50* | +25.50 | -22.50 | — | — | |

* These are significantly better than the female parent.

TABLE 2

| Parents and hybrids | Plant height (cm) | | | Number of racemes | | | Length of primary raceme (cm) | | | Length of male and female portion of primary raceme | | |
|---------------------|--|-----------------|------------|--|-----------------|------------|--|-----------------|-------------------|--|--------------------|------------|
| | Percentage increase or decrease of F ₁ over | | Mean value | Percentage increase or decrease of F ₁ over | | Mean value | Percentage increase or decrease of F ₁ over | | Mean value | Percentage increase or decrease of F ₁ over | | Mean value |
| | Mean value of two parents | Superior parent | | Mean value of two parents | Superior parent | | Mean value of two parents | Superior parent | | Mean value of two parents | Superior parent | |
| 1. .. | 81.05 | — | 6.20 | — | — | 38.25 | — | — | *12.95 **25.30 | — | — | — |
| 2. .. | 15.95 | — | 14.37 | — | — | 15.70 | — | — | 8.40 7.30 | — | — | — |
| 3. .. | 27.10 | - 44.12 | **17.02 | + 65.55 | + 18.44 | 27.96 | + 3.67 | - 26.90 | **14.65 13.30 | + 37.17 - 20.24 | + 13.13 - 47.43 | — |
| 4. .. | 134.40 | — | 3.00 | — | — | 26.50 | — | — | 12.40 14.10 | — | — | — |
| 5. .. | 27.40 | - 63.54 | **14.95 | + 73.02 | + 4.02 | 26.61 | + 16.11 | + 0.41 | *18.47 8.14 | + 77.59 - 23.92 | + 48.95 - 42.26 | — |
| 6. .. | 143.15 | — | 4.25 | — | — | 24.94 | — | — | 10.44 14.50 | — | — | — |
| 7. .. | 33.45 | - 57.95 | **17.60 | + 89.04 | + 22.47 | 26.05 | + 28.19 | + 4.45 | *17.53 8.53 | + 86.09 - 22.66 | + 67.91 - 41.17 | — |
| 8. .. | 45.50 | — | 4.00 | — | — | 25.45 | — | — | 8.45 17.00 | — | — | — |
| 9. .. | 69.56 | + 9.94 | **9.28 | + 81.96 | + 49.67 | 37.05 | + 17.69 | - 3.13 | 12.50 24.55 | + 16.81 + 16.07 | - 3.47 - 2.96 | — |
| 10. .. | 95.43 | + 6.09 | 4.07 | + 16.28 | + 26.75 | 29.55 | + 13.74 | + 11.50 | 11.92 17.63 | + 14.09 + 13.37 | - 4.03 + 3.70 | — |
| 11. .. | 95.90 | + 1.67 | *7.17 | + 73.46 | + 68.70 | 26.15 | + 3.76 | + 2.75 | **12.55 13.60 | + 33.08 - 13.65 | + 20.21 - 20.00 | — |

** These are significantly superior to mid-parental value.

* These are significantly superior to the better parent.

** Female portion.

* Male portion.

TABLE 3

| Parents and hybrids | Number of capsules set on each plant | | | Yield of beans (gm) | | | Mean wt. of 25 beans (gm) | | | Oil content (%), Mean of two replications |
|---------------------|--------------------------------------|--|-----------------|---------------------|--|-----------------|---------------------------|--|-----------------|---|
| | Mean value | Percentage increase or decrease of F ₁ over | | Mean value | Percentage increase or decrease of F ₁ over | | Mean value | Percentage increase or decrease of F ₁ over | | |
| | | Mean value of two parents | Superior parent | | Mean value of two parents | Superior parent | | Mean value of two parents | Superior parent | |
| 1. .. | 139.32 | — | — | 76.94 | — | — | 5.72 | — | — | 53.61 |
| 2. .. | 118.60 | — | — | 63.86 | — | — | 3.99 | — | — | 45.43 |
| 3. .. | 222.37* | +72.43 | +59.61 | 127.26* | +80.76 | +65.41 | 5.79** | +19.38 | +2.44 | 49.35 |
| 4. .. | 127.65 | — | — | 83.27 | — | — | 7.80 | — | — | 53.86 |
| 5. .. | 183.27* | +48.83 | +43.57 | 125.45* | +70.54 | +50.65 | 7.01** | +19.01 | -10.12 | 49.97 |
| 6. .. | 136.17 | — | — | 89.61 | — | — | 8.32 | — | — | 53.19 |
| 7. .. | 226.10* | +77.50 | +66.04 | 158.27* | +106.26 | +76.62 | 7.30 | +8.14 | -12.25 | 49.56 |
| 8. .. | 54.07 | — | — | 36.31 | — | — | 7.03 | — | — | 45.98 |
| 9. .. | 205.15* | +112.17 | +47.25 | 106.00* | +87.21 | +33.77 | 8.37 | +31.39 | +19.06 | 53.39 |
| 10. .. | 139.87** | +53.94 | +9.57 | 90.73 | +51.74 | +8.95 | 8.69* | +17.27 | +11.41 | 47.72 |
| 11. .. | 149.57** | +57.24 | +9.84 | 139.28* | +121.21 | +55.42 | 9.81* | +27.90 | +17.87 | 49.90 |

** These are significantly superior to mid-parental value.

* These are significantly superior to the better parent.

the mean of the two parents or higher parental value in the production of racemes. In the case of hybrids TMV 1 \times Baker-195, TMV 2 \times Baker-195, TMV 3 \times Baker-195 and TMV 1 \times Cimarron, hybrid vigour in the production of racemes was indicated by the significantly higher values over the mid-parental value. The hybrid TMV 3 \times Cimarron alone had exceeded the value of the superior parent.

Length of primary raceme and sex distribution. In the length of the primary raceme, the hybrids did not show any significant increase. But, positive increase over the mid-parental value was exhibited by the combinations, TMV 1 with Baker-195, and Cimarron while other hybrids recorded positive increases over the value of the superior parent. With regard to sex distribution on the primary raceme, all combinations (except TMV 1 \times Cimarron and TMV 2 \times Cimarron) exhibited significant increases in the length of the male flower bearing portion, over the parents having the greater length of male flower bearing portion. In respect of the female flower bearing portion, no significant increase over either the parental mean or higher parental value is noticed in any of the hybrids.

Number of capsules. Significant heterosis in the number of capsules set on all the racemes produced by the plant was obtained in four out of the six hybrids. The two hybrids TMV 2 \times Cimarron and TMV 3 \times Cimarron exhibited significantly positive increases over the mid-parental values.

Bean yield. Marked heterosis in yield of beans was obtained in all the hybrids, except TMV 1 \times Cimarron and TMV 2 \times Cimarron. Significantly positive increase in bean production over the mid-parental value only was expressed by TMV 1 \times Cimarron. The hybrids, TMV 1 \times Baker-195, TMV 2 \times Baker-195, and TMV 3 \times Baker-195 showed increased yield of 65.41, 50.65 and 76.62 per cent, respectively, over their superior parents. With Cimarron as the pollen parent, only TMV 3 exhibited a higher yield of 55.42 per cent. The hybrid TMV 1 \times Cimarron expressed a significant difference over its mid-parental value, whereas TMV 2 \times Cimarron did not

exhibit any significant difference from the mid-parental value. The percentage of increase in yield was not found to be uniform in all the six hybrids studied. This may be said to be due to the genetic differentiation among the parent types utilised in hybridisation.

Mean bean weight. Heterosis in seed weight was observed in all the three hybrids where Cimarron was used as one of the parents. The values in these exceed those of the parents with greater seed weight. Positive deviations from the mid-parental values only were observed in the case of TMV 1 \times Baker-195 and TMV 2 \times Baker-195.

Duration of crop (Number of days for final harvest). All the six hybrids showed intermediate values between the duration of the parents. Even in cases where earlier flowering was noticed, in some hybrids the duration for final harvests was extended.

Oil content. The mean oil content in beans obtained from the inbred parents and the hybrids estimated by the ether-extraction method showed that there was no increase in the oil content in the produce of the hybrids.

It is observed from the above that significant heterosis was noticed in number of racemes produced per plant, number of capsules set per plant, bean weight and total yield of beans. In respect of number of days taken for first flowering, some of the hybrids show a tendency to be as early as the male parents, sharply deviating from the female parents, the values for the hybrids being less than even the mid-parent values. However, this was not reflected in the duration for final harvest, all the hybrids being intermediate in the duration between the two parents. The plant height in all hybrids was intermediate and there was no indication of heterosis.

The variation in yield of beans was again significant. Hybrids TMV 3 \times Baker-195, TMV 1 \times Baker-195 and TMV 3 \times Cimarron and TMV 2 \times Baker-195 had given significantly higher yield of beans over the superior parents, the increases ranging from

50.65 to 76.62 per cent. The performance of the other hybrids was not noteworthy.

The attributes related to the final bean yield, viz., total number of capsules, number of racemes and the mean bean weight did not show the same trend as the total yield of beans. The total number of capsules, however, appeared to show a heterotic expression similar to the yield of beans.

The variation in yield resulting from the differences in manifestation of heterosis could be attributed in these cases to the genetic diversity in the parents. An exact estimate of the general combining ability is not possible from these studies, yet it is evident that parents like TMV 3 \times TMV 1 have high specific combining ability with Baker-195. Methods for the exploitation of the high combining ability noticed in the hybrids, through the utilisation of the pistillate character (Zimmerman and Parkey 1959) for production of hybrid seed, have to be developed in further investigations. This is in consonance with the earlier observations of Borkovskii and Podgurskaja (1937) who stressed that only some combinations of inbred lines exhibited heterosis. According to Stein (1958) it should prove feasible to find parental combinations giving progenies which show only the produce effect and are, therefore, more efficient producers. Anubhuva Narayan (1958) found that the manifestation of hybrid vigour in yield varied in F_1 s, ranging from 2.7 to 277.00 per cent over the higher yielding parent. The maximum average increase in F_1 over the highest yielding parent entering the crosses was about 22.9 per cent. Zimmerman (1958) reported seed yields ranging from 109 to 130 per cent over the higher yielding parent, in some of the hybrids. Aiyadurai *et al* (1960) have reported that increased yield ranging from 2.1 to 34.3 per cent over the female parent have been obtained from hybrids involving TMV 1 as female parent and selected breeds of Russian and Egyptian origin, as pollen parents. It may be said that the three combinations, TMV 3 \times Baker-195, TMV 1 \times Baker-195 and TMV 3 \times Cimarron which have as observed now shown increased yield, may be consi-

dered as useful combinations for practical exploitation.

Summary

Three standard castor strains of Madras State, namely TMV 1, TMV 2, and TMV 3 were crossed with two American types, Baker-195 and Cimarron, as pollen parents. Observations were recorded on flowering date, plant height, number of nodes, number of racemes, length of main raceme, length of male and female portions of the main raceme, number of capsules set on each plant, yield of beans, mean bean weight, duration of crop and oil content in the parents and hybrids.

In the production of racemes, all the hybrids (except TMV 2 \times Cimarron) exhibited heterotic vigour. In the production of capsules, hybrids of the combination, TMV 1, TMV 2 and TMV 3 with Baker-195 and TMV 1 \times Cimarron exhibited transgressive heterosis while hybrids of TMV 2 \times Cimarron and TMV 3 \times Cimarron exhibited significant positive increase over their parental mean. With regard to sex distribution on the primary raceme, all combinations (except TMV 1 \times Cimarron and TMV 2 \times Cimarron) exhibited increase in length of the male flower bearing portion only. In respect of the female flower bearing portion none of the hybrids showed any significant increase over either the parental mean or the higher parental value.

Heterosis was observed in the mean weight of the beans obtained from the hybrids of TMV 1 \times Cimarron, TMV 2 \times Cimarron and TMV 3 \times Cimarron. In the hybrids where Baker-195 was used as the pollen parent positive deviations from the mid-parental value were recorded. In respect of duration, all the six hybrids exhibited significant earliness over the long duration (female) parents, but they were intermediate between the two parents in each case.

Among the six hybrids studied, three viz., TMV 3 \times Baker-195, TMV 1 \times Baker 195 and TMV 3 \times Cimarron, have shown increased yield over the parents. The variability in the manifestation of heterosis

noticed in the sets of crosses studied points to the differential combining ability of the parents involved, brought about by the genetic diversity.

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